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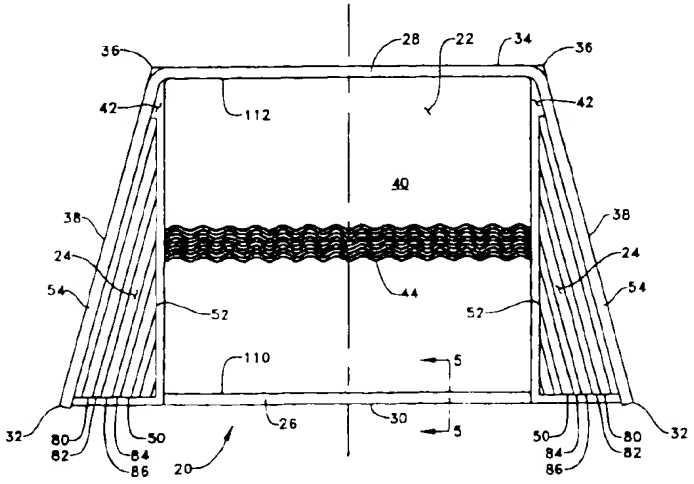

(57) Abstract

surface heat exchanger or recuperator (6), the plurality of cells (8) needs to be manufactured to more effectively withstand these inputs. The application of the unitary "U" bar (28) and the unitary plurality of spacer bars (40) increases the effectiveness of the plurality of cells (8) to withstand these loads, cycles and stresses. Thus, the stress at individual ends (36) is made stronger with the unitary "U" bar (28) versus using a plurality of individual components to make up the "U" bar (28). Additionally, the use of fewer parts reduces cost of components and labor to assemble the plurality of cells (8).

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Description

IMPROVED METHOD FOR MAKING A RECUPERATOR CELL

Technical Field

This invention relates generally to a primary surface heat exchanger and more particularly to a method of making a plurality of cell used to form the primary surface heat exchanger.

Background Art

Many gas turbine engines use a heat exchanger of recuperator to increase the operation efficiency of the engine by extracting heat from the exhaust gas and preheating the combustion air. Typically, a recuperator for a gas turbine engine must be capable of operating at temperatures of between about 500 degrees C. and 800 degrees C. and internal pressures of between approximately 140 kPa and 1400 kPa under operating conditions involving repeated starting and stopping cycles.

Such recuperators include a core which is commonly constructed of a plurality of relatively thin flat sheets having an angled or corrugated spacer fixedly attached therebetween. The sheets are joined into cells, sealed and form passages between the sheets. These cells are stacked or rolled and form alternate air (recipient) cells and hot exhaust (donor) cells. Compressed discharged air from a compressor of the engine passes through the air cell while hot exhaust gas flows through alternate cells.

[illegible] the sheets and spacers.

An example such a recuperator is disclosed in U.S. patent No. 5,060,721 issued to Charles T. Darragh on 29 October 1991. In such a system, Darragh discloses a heat exchanger having been used to increase the efficiency of engine by absorbing heat from the exhaust gases and transferring a portion of the exhaust heat to the combustion air. The heat exchanger is built-up from a plurality of performed involute curved cells stacked in a circular array to provide flow passages and for the donor fluid and the recipient fluid respectively.

Recuperators used with gas turbine engines have structures in which very high stresses are induced. For example, recuperators must operate at temperatures of between about 500 degrees C. and 800 degrees C. and internal pressures of between approximately 140 kPa and 1400 kPa. Under normal operating conditions repeated starting and stopping cycles are common. Many of the starts are considered to be hot starts. With the hot donor fluid being at a temperatures of between about 500 degrees C. and 800 degrees C. and the recipient fluid being near an atmospheric temperatures of between about 0 degrees C. and 60 degrees C., the thermal difference or gradients experienced by the recuperator is extremely high. Thus, the thermal stress induced in also extremely high.

The present invention is directed to overcoming one or more of the problems as set forth above.

Disclosure of the Invention

primary surface sheets. Each of the pair of primary surface sheets has a donor side and a recipient side, a base edge defining a pair of ends, an outer edge being spaced from the base edge and defining a pair of ends, and a pair of extension edges extending between the respective pair of ends. Each of the pair of primary surface sheets further has a center portion extending between the base edge and the outer edge and has a wing portion interposed the center portion and each of the pair of extension edges. A plurality of spacer bars has one of the plurality of spacer bars positioned at the outer edge on the donor side of one of the pair of primary surface sheets and another one of the plurality of spacer bars positioned at the base edge on the donor side of the same one of the pair of primary surface sheets. Each of the plurality of spacer bars is of a unitary construction. A "U" bar is positioned along the outer edge and the pair of extension edges on the recipient side of the one of the pair of primary surface sheets. The "U" bar is of a unitary construction. A pair of guide strips are positioned within the wing portion on the recipient side of the one of the pair of primary surface sheets. A second one of the pair of primary surface sheets has one of the plurality of spacer bars positioned at the outer edge on the donor side of one of the pair of primary surface sheets and another one of the plurality of spacer bars is positioned at the base edge on the donor side of the same one of the pair of primary surface sheets. Each of the plurality of spacer bars is of a unitary construction. The second one of the primary surface sheets is positioned

positioned within the wing portion on the donor side of the second one of the pair of primary surface sheets.

In another aspect of the invention, a cell is comprised of a pair of primary surface sheets. Each of the primary surface sheets have a base edge defining a pair of ends, an outer edge being spaced from the base edge and defining a pair of ends, and a pair of extension edges extending between the respective pair of ends. Each of the primary surface sheets further have a center portion extending between the base edge and the outer edge and have a wing portion interposed the center portion and each of the pair of extension edges. The cell is further comprised of a spacer bar positioned along the base edge and have a length corresponding to the base edge of the center portion. The spacer bar is of a unitary construction. The cell is further comprised of a "U" bar positioned along the outer edge and the pair of extension edges. The "U" bar is of a unitary construction.

Brief Description of the Drawings

FIG. 1 is a sectional view of a heat exchanger of recuperator embodying the present invention;

FIG. 2 is an enlarged sectional view of a cell taken along line 2-2 of FIG. 1;

FIG. 3 is an enlarged cross-sectional view of the cell taken along line 3-3 of FIG. 1 showing the recipient side of the cell;

FIG. 4 is an enlarged cross-sectional view

FIG. 5 is an enlarged cross-sectional view taken along line 5-5 of FIG. 3;

FIG. 6 is profile view of a single piece "U" bar; and

FIG. 7 is an enlarged cross-sectional view taken along line 7-7 of FIG. 6.

Best Mode for Carrying Out the Invention

Referring to FIGS. 1, 2 and 3, a heat exchanger or recuperator 6 includes a plurality of individual cells 8 fixedly attached to form the recuperator 6 which in this application has a circular construction. The recuperator 6 defines an inner diameter 10 and an outer diameter 12. The plurality of cells 8 are formed and have either a passage 14 for donor fluid to flow therethrough contacting a donor side 16 or a passage 18 for recipient fluid to flow therethrough contacting a recipient side 20. The passage 14,18 are alternately positioned within the circular recuperator 10. In this application, each of the plurality of cells 8 have an involute configuration. Each of the plurality of individual cells 8 is formed of a pair of primary surface sheet 22 and a pair of guide strips 24. As best shown in FIGS 3, 4 and 5, each of the plurality of individual cells is further formed of a plurality of spacer bars 26 and a "U" bar 28.

In this application, the pair of primary surface sheets 22 are generally identical in configuration. Each of the pair of primary surface sheets 22 includes a base edge 30 having a preestablished length defining a pair of ends 32. The

base edge 30. The outer edge 34 is defined on each of the pair of primary surface sheets 22 has a preestablished length and defines a pair of ends 36 positioned opposite the base edge 30. In this application, the outer edge 34 is generally parallel with the base edge 30 and has the preestablished length being less than the preestablished length of the base edge 30. Extending between the base edge 30 and the outer edge 34 and connecting corresponding ones of the pair of ends 32,36 are a pair of extension edges 38. Each of the pair of primary surface sheets 22 includes a center portion 40 extending between the base edge 30 and the outer edge 34. Interposed the center portion 40 and each of the pair of extension edges 38 is a wing portion 42. In this application, the center portion 40 has a generally rectangular configuration and the wing portions 42 have a generally triangular configuration. The center portion 40 includes a plurality of pleats 44 defining a peak 46 and a valley 48 and the wing portions 42 are flat or have been flattened, void of the peaks 46 and valleys 48.

Additionally, the pair of guide strips 24 positioned on each of the donor side 16 of the cell 8 and the recipient side 20 of the cell 8. The pair of guide strips 24 have a distinct geometric configuration which in this application is of a different configuration or construction depending on which side the cell 8 the pair of guide strips 24 are positioned. For example, in this application, the guide strip 24 used in conjunction with the donor side 16 and the recipient side 20 have a generally common

thereof defines an axial portion 56 which extends from the height 52. A first extension member 58 extends from the axial portion 56 and a top portion 60 extends axially from the extension member 58. The top portion 60 is generally parallel with the axial portion 56 and a second extension member 62 extends from the top portion 60 toward a second repletion of the axial portion 56 etc. However, the guide strips 24 for the recipient side 20 when viewed through a cross-section thereof defines an axial portion 80 extending from the base 50. A first extension member 82 extends from the axial portion 80 and a top portion 84 extends axially from the first extension member 82. The top portion 84 is generally parallel with the axial portion 80 and a second extension member 86 extends from the top portion 84 toward a second repletion of the axial portion 80 etc.

As further shown in FIGS. 3, 4 and 5, the plurality of spacer bars 26 are made of a first preestablished thickness "T1" and a second preestablished thickness "T2" being greater than that of the first preestablished thickness "T1". Such that the outer faces of the plurality of spacer bars 26 have a distance therebetween being equal to the distance therebetween the pair of peaks 46 of the corresponding plurality of pleats 44. Furthermore the plurality of spacer bars 26 vary in length. The spacer bars 26 having the first preestablished thickness "T1" are positioned near the outer edge 34 on the donor side 16 of the pair of primary surface sheets 22. The spacer bars 26 having the second preestablished thickness "T2" being positioned near the [illegible] on the recipient side 20 of the pair

that of the second preestablished thickness "T2" and, in this application, is positioned on the recipient side 20 of the pair of primary surface sheets 22. Thus, the "U" bar 28 has a preestablished thickness "T2" and a preestablished width "W", as is best shown in FIG. 7. In this application, the "U" bar 28 is as thick as the second preestablished thickness "T2" of the spacer bars 26 and is about twice the thickness as the first preestablished thickness "T1" of the spacer bars 26. The "U" bar 28 further includes a base 90 and a pair of legs 92 extending from the base 90. The pair of legs 92 define a first end portion 94 having a preestablished configuration and a second end portion 96 attached to the base 90. Interposed the base 90 and the second end portion 96 of the pair of legs 92 is a radiused portion 98 forming a uniform transition between the base 90 and the pair of legs 92. In this application, the pair of legs 92 join with the base 90 and extend therefrom at an included angle of about 105 degrees. The first end portion 94 is cut or trimmed to form an angled end 100. In this application, the angled end 100 is about 15 degrees. However, as an alternative the angled end 100 could be other than a 15 degree angle and could be a 90 degree angle or a square end.

In this application, the individual cells 8 have a passage 18 for the recipient fluid to flow therethrough. The passage 18 of the individual cells form an inner perimeter 110 and an outer perimeter 112. The inner perimeter 110 includes one of the plurality of spacer bars 26 having the second preestablished thickness "T2" and being a single

[illegible] positioned between the two

[illegible] corresponding [illegible]

perimeter 110 is sealingly secured, in this application by welding. The welding process further sealingly secures the one of the plurality of spacer bars 26 positioned on the donor side 16 of the two primary surface sheets 22 at the base edge 30 between the pair of ends 32. The outer perimeter 112 includes the "U" bar 28 being a single unitary bar. The "U" bar 28 is positioned between the two primary surface sheets 22 along the pair of extension edges 38 and the outer edge 34. The outer perimeter 112 is sealingly secured, in this application by welding. The welding process further sealingly secures the one of the plurality of spacer bars 26 positioned on the donor side 16 of the two primary surface sheets 22 at the outer edge 34.

In this application, the cells 8 are formed by a fixture, not shown. The fixture positions the components of the cell 8, forms the components and maintains the components in a preestablished position and form while the components are fixedly secured one to the other. As an alternative, the components of the cell 8 could be formed prior to being positioned and fixedly secured. Or, as a further alternative, the components of the cell 8 could be positioned and fixedly secured prior to being formed.

Industrial Applicability

During the fixturing and forming of the cell 8, the relative components are positioned. One example of such a fixturing would be as follows, with the components parts in the unbent form, one of the primary surface sheets 22 is positioned with the donor

is positioned along the base edge 30. Another one of the plurality of spacer bars 26 having the first preestablished thickness "T1" and the length corresponding to the length of the outer edge 34 is positioned along the outer edge 34. Next, a portion of the base edge 30 of the primary surface sheet 22 is welded to the one of the plurality of spacer bars 26 positioned along the inner edge 30. And, the outer edge 34 of the primary surface sheet 22 is tack welded to the another one of the plurality of spacer bars 26. The primary surface sheet 22 with one of the plurality of spacer bars 26 attached at the outer edge 34 and the base edge 30 is rotated to position the recipient side 20 up. And, the pair of the guide strips 24 having the axial portion 80 extending from the base 50 is positioned in each of the wing portions 42. And, the "U" bar 28 having the thickness "T2" is positioned with the base 90 corresponding to the outer edge 34 and each of the pair of legs 92 corresponding to the respective pair of extension edges 38. At this point, the additional components are tack welded or attached to the recipient side 20 of the primary surface sheet 22.

Next, an additional one of the primary surface sheet 22 is positioned symmetrically about the existing one of the primary surface sheet 22 with the recipient side 20 down and the donor side 16 up. Thus, recipient sides 20 face one another. One of the plurality of spacer bars 26 having the first preestablished thickness "T1" and the length corresponding to the length of the base edge 30 is positioned along the base edge 30. Another one of the

positioned along the outer edge 34. The component parts are tacked. The components of the one of the plurality of cells are placed in a fixture, formed to an involute and welded. As a further alternative, the components parts could be formed prior to being positioned within the fixture. And, the pair of the guide strips 24 having the axial portion 56 extending from the height 52 is positioned in each of the wing portions 42. The pair of guide strips 24 is, in this application, tacked. As an alternative the pair of guide strips 24 could be attached by other conventional methods such as an adhesive.

In the welding of the cell 8, a portion of the edges are welded and a portion of the edges are free of weld. For example, the weld begins at one of the pair of ends 32, continues along one of the pair of extension edges 28, continues along the outer edge 34 and continues along the other of the pair of extension edges 28 to the other of the pair of ends 32. Another weld extends along the base 30 of the center portion 40. The base 30 along the wing portions 42 has each of the plurality of spacer bars 26 having the first preestablished thickness "T1" on the donor side 16 attached to the corresponding one of the primary surface sheets 22. The space or portion of the passage 14 between the primary surface sheets 22 having the guide strips 24 therein and corresponding to the base 50 is free of weld. This passage 14 provides the flow path for the recipient fluid into and along the wing portion 42, along the center portion 40 and passing along the wing portion 42 and escaping therefrom.

the outer diameter 12. And, the corresponding plurality of spacer bars 26 having the first preestablished thickness "T1" and being attached to the donor side 16 of the primary surface sheets 22 of the cells 8 are welded along the base edge 30 from one of the pair of ends 32 to the other pair of ends 32. Additionally, the corresponding plurality of spacer bars 26 having the first preestablished thickness "T1" and being attached to the donor side 16 of the primary surface sheets 22 of the cells 8 are welded along the outer edge 30 from one of the pair of ends 36 to the other of the pair of ends 36. This operation continues until each of the cells 8 are sealingly connected one to the other forming the passage 14 for the flow of donor fluid and the passage 18 for the flow of recipient fluid. For example, the space or portion of the passage 18 between the primary surface sheets 22 having the guide strips 24 therein and corresponding to the base 50 provides the flow path for the recipient fluid. The recipient fluid flows into and along the wing portion 42, along the center portion 40 and passes along the wing portion 42 and escapes therefrom. And, the space between the corresponding one of the pair of extension edges 38 of the individual primary surface sheets 22 of the cell 8 corresponding to the hypotenuse 54 provides the passage 14 for the flow of the donor fluid. The donor fluid flows into and along the wing portion 42, along the center portion 40 and passes along the wing portion 42 and escapes therefrom.

The recuperator 6 has a structure in which very high stresses are induced. For example, the

and 1400 kPa under operating conditions involving repeated and rapid starting and stopping cycles. With the hot donor fluid being at a temperatures of between about 500 degrees C. and 700 degrees C. and the recipient fluid being near an atmospheric temperatures of between about 0 degrees C. and 60 degrees C., the thermal difference experienced by the recuperator 6 is extremely high resulting in the thermal stress induced therein also being extremely high. With the "U" bar 28 being a single unitary bar or a continuous bar, verses a segmented bar, this stress is better resisted increasing the life and longevity of the recuperator 6.

Claims

1. A recuperator (6) being formed by a plurality of cells (8), each of said plurality of cell (8) comprising:

a pair of primary surface sheets (22), each of said pair of primary surface sheets (22) having a donor side (16) and a recipient side (20), having a base edge (30) defining a pair of ends (32), an outer edge (34) being spaced from said base edge (30) and defining a pair of ends (36), and a pair of extension edges (38) extending between said respective pair of ends (32,36), each of said pair of primary surface sheets (22) further having a center portion (40) extending between said base edge (30) and said outer edge (34) and having a wing portion (42) being interposed said center portion (40) and each of said pair of extension edges (38);

a plurality of spacer bars (26), one of said plurality of spacer bars (26) being positioned at said outer edge (34) on said donor side (16) of one of said pair of primary surface sheets (22) and another one of said plurality of spacer bars (26) being positioned at said base edge (30) on said donor side (16) of said same one of said pair of primary surface sheets (22), each of said plurality of spacer bars (26) being of a unitary construction;

a "U" bar (28) being positioned along said outer edge (34) and said pair of extension edges (38) on said recipient side (20) of said one of said pair of primary surface sheets (22), said "U" bar (28) being of a unitary construction;

(20) of said one of said pair of primary surface sheets (22);

a second one of said pair of primary surface sheets (22) having one of said plurality of spacer bars (26) being positioned at said outer edge (34) on said donor side (16) of one of said pair of primary surface sheets (22) and another one of said plurality of spacer bars (26) being positioned at said base edge (30) on said donor side (16) of said same one of said pair of primary surface sheets (22), each of said plurality of spacer bars (26) being of a unitary construction;

said second one of said primary surface sheets (22) being positioned symmetrically about said one of said primary surface sheets (22), said recipient side (20) being positioned facing one another;

and a second pair of guide strips (24) being positioned within said wing portion (42) on said donor side (16) of said second one of said pair of primary surface sheets (22).

2. The recuperator (6) of claim 1 wherein each of said plurality of cells (8) further define a flow passage (14,18) having an inner perimeter (110) and an outer perimeter (112), said inner perimeter (110) being formed by said pair of primary surface sheets (22) and said unitary spacer bar (26) and said outer perimeter (112) being formed by said pair of primary surface sheets (22) and said unitary "U" bar.

3. The recuperator (6) of claim 2 wherein

said unitary spacer bar (26) and said pair of primary surface sheets (22) and said unitary "U" bar (28).

4. The recuperator (6) of claim 3 wherein said sealing formed by welding includes a continuous weld along said inner perimeter (110) and a continuous weld along said outer perimeter (112).

5. The recuperator (6) of claim 1 wherein said recuperator (6) has a circular configuration defining an inner diameter (10) and an outer diameter (12).

6. The recuperator (6) of claim 5 wherein said inner diameter (10) is formed by each of said plurality of cells (8) being welded one to the other along said base edge (30).

7. The recuperator (6) of claim 5 wherein said outer diameter (12) is formed by each of said plurality of cells (8) being welded one to the other along said outer edge (34).

8. The recuperator (6) of claim 1 wherein each of said plurality of cells (8) include a guide strips (24) positioned in said wing portion (42).

9. The recuperator (6) of claim 1 wherein said plurality of cells (8) are attached by welding.

10. A cell (8) comprising:

a pair of primary surface sheets (22), each

pair of ends (36), and a pair of extension edges (38) extending between said respective pair of ends (32,36), each of said primary surface sheets (22) further having a center portion (40) extending between said base edge (30) and said outer edge (34) and having a wing portion (42) being interposed said center portion (40) and each of said pair of extension edges (38);

a spacer bar (26) being positioned along said base edge (30) and having a length corresponding to said base edge (30) of said center portion (40), said spacer bar (26) being of a unitary construction; and

a "U" bar (28) being positioned along said outer edge (34) and said pair of extension edges (38), said "U" bar (28) being of a unitary construction.

11. The cell (8) of claim 10 wherein said cell (8) further defines a flow passage (14,18) having an inner perimeter (110) and an outer perimeter (112), said inner perimeter (110) being formed by said pair of primary surface sheets (22) and said unitary spacer bar (26) and said outer perimeter (112) being formed by said pair of primary surface sheets (22) and said unitary "U" bar.

12. The cell (8) of claim 11 wherein said flow passage (14,18) formed within said cell (8) being sealingly formed by welding said pair of primary surface sheets (22) and said unitary spacer bar (26) and said pair of primary surface sheets (22) and said unitary "U" bar (28).

along said inner perimeter (110) and a continuous weld along said outer perimeter (112).

14. The cell (8) of claim 10 wherein said cell (8) has an involute configuration.

15. The cell (8) of claim 10 wherein a guide strips (24) being positioned in said wing portion (42).

16. The cell (8) of claim 10 wherein said "U" bar has a preestablished thickness "T2".

17. The cell (8) of claim 16 wherein said spacer bar (26) has a preestablished thickness "T1" being about half as thick as said preestablished thickness "T2" of said "U" bar (28).

18. The cell (8) of claim 10 wherein each of said pair of primary surface sheets (22) define a donor side (16) and a recipient side (18).

19. The cell (8) of claim 18 wherein said recipient side (18) of each pair of primary sheets (22) face each other.

20. The cell (8) of claim 18 wherein said donor side (16) having a space bar (26) sealingly attached at said inner edge (30) extending from said pair of ends (32) and an other of said spacer bars (26) being sealingly attached at said outer edge (34) extending from said pair of ends (36).

Fig. 1

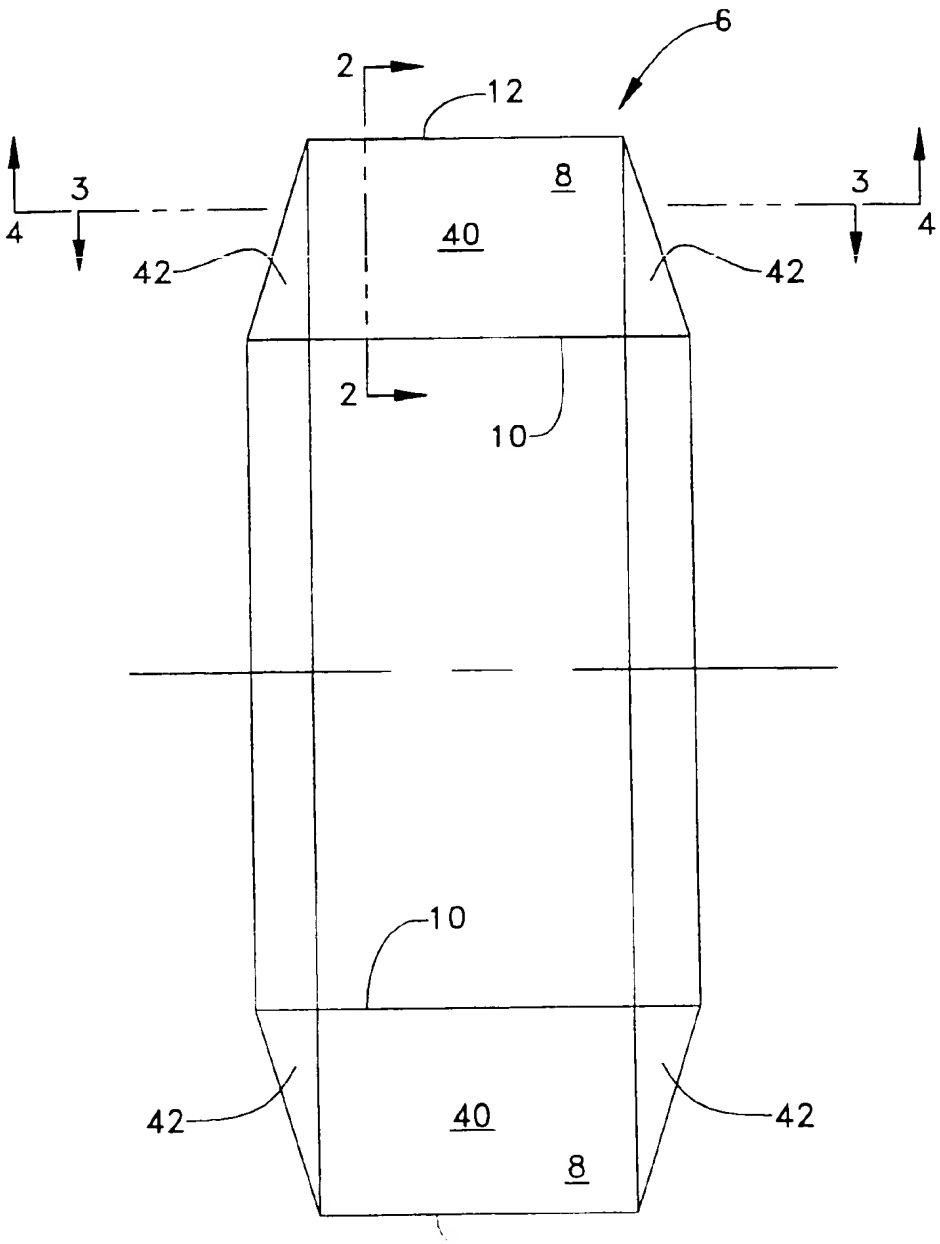
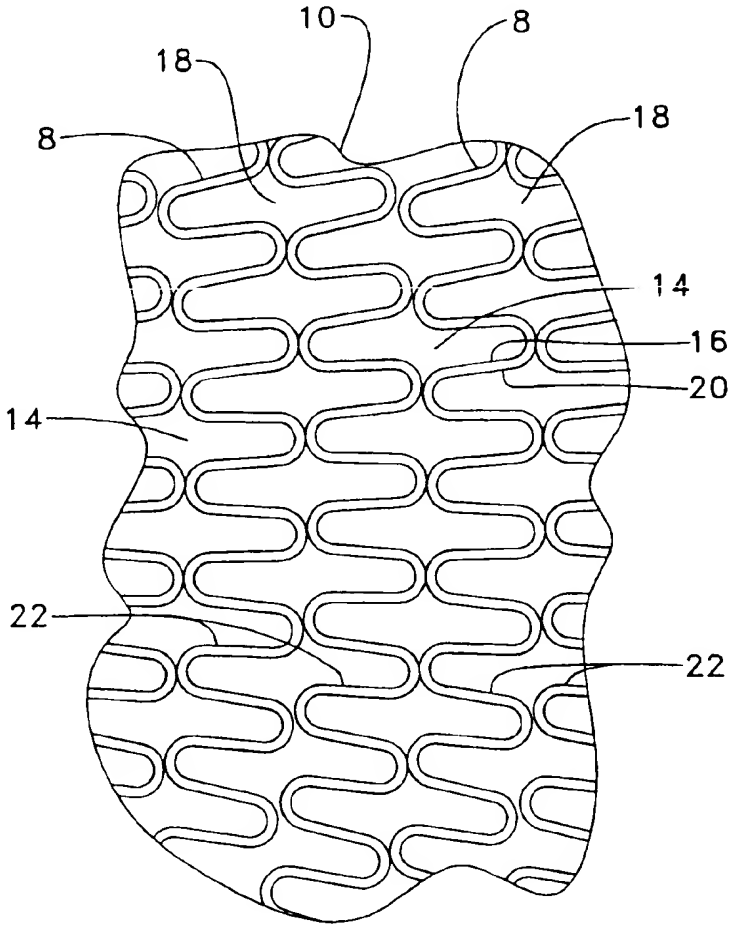


Fig_2_



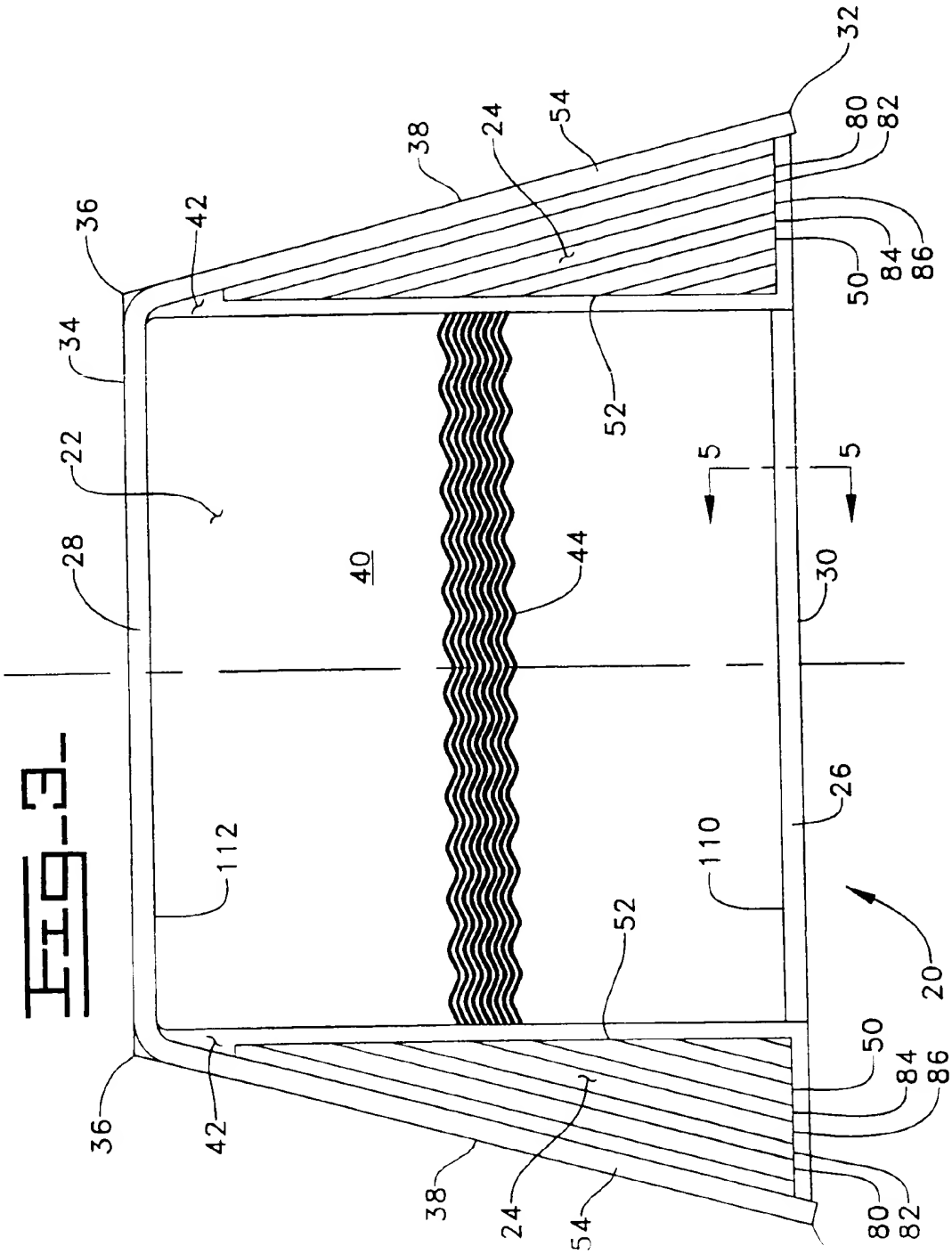

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FIG-3-

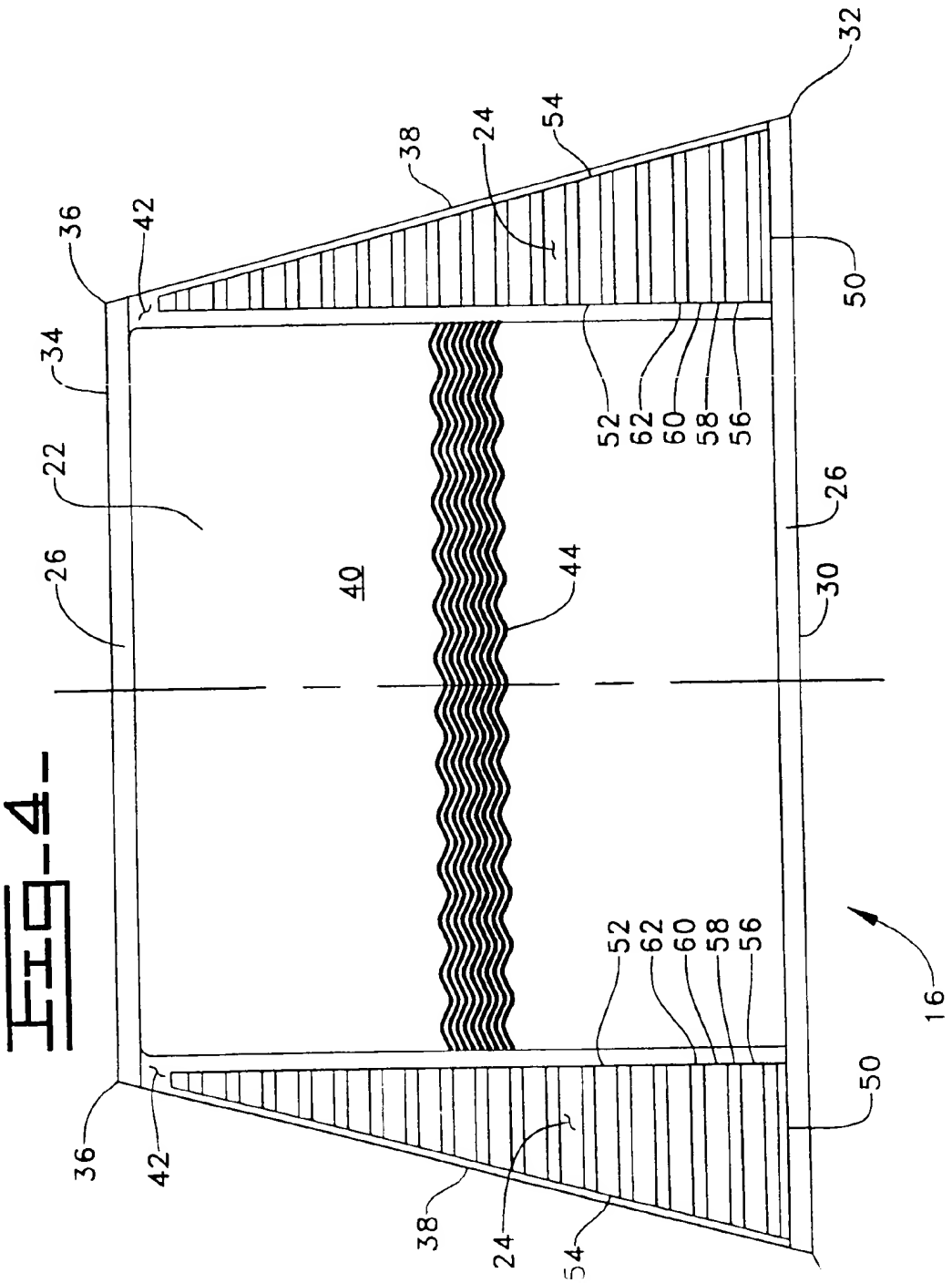
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Fig-4-

Fig_5_

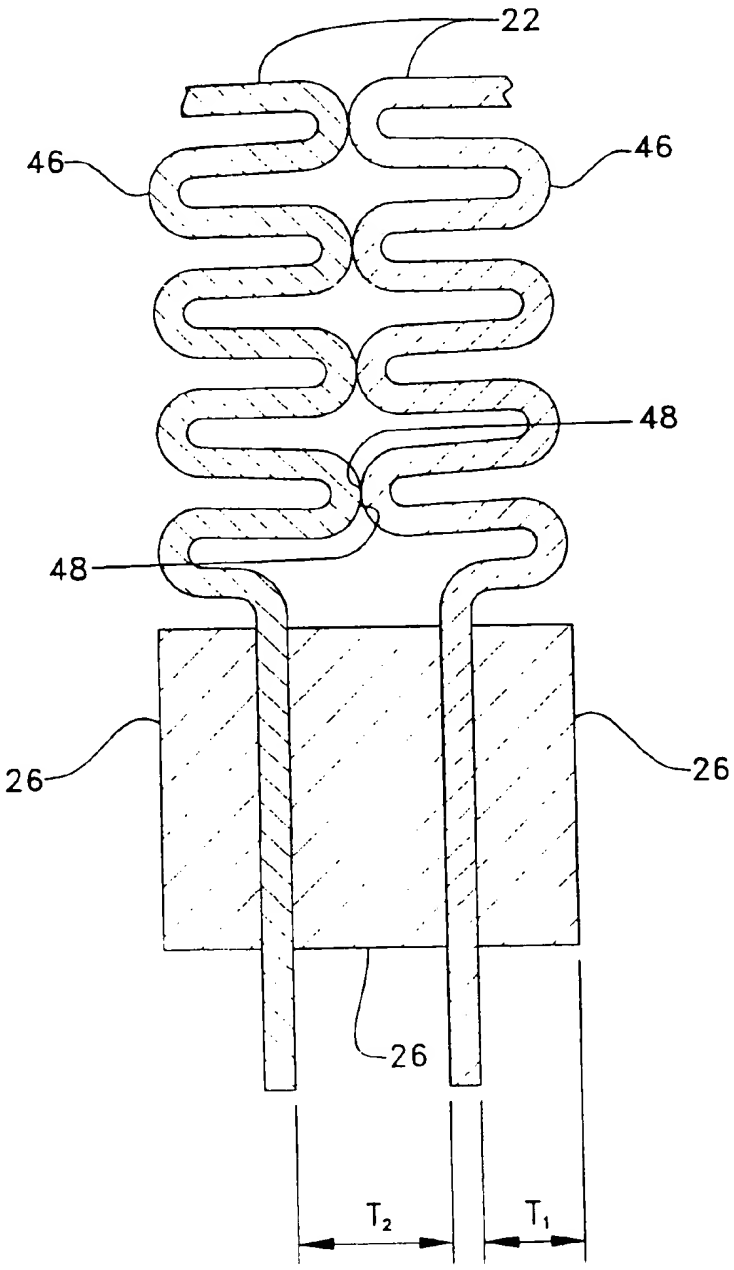


FIG-7

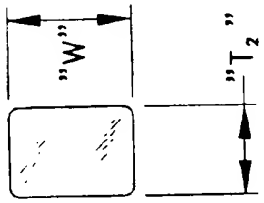
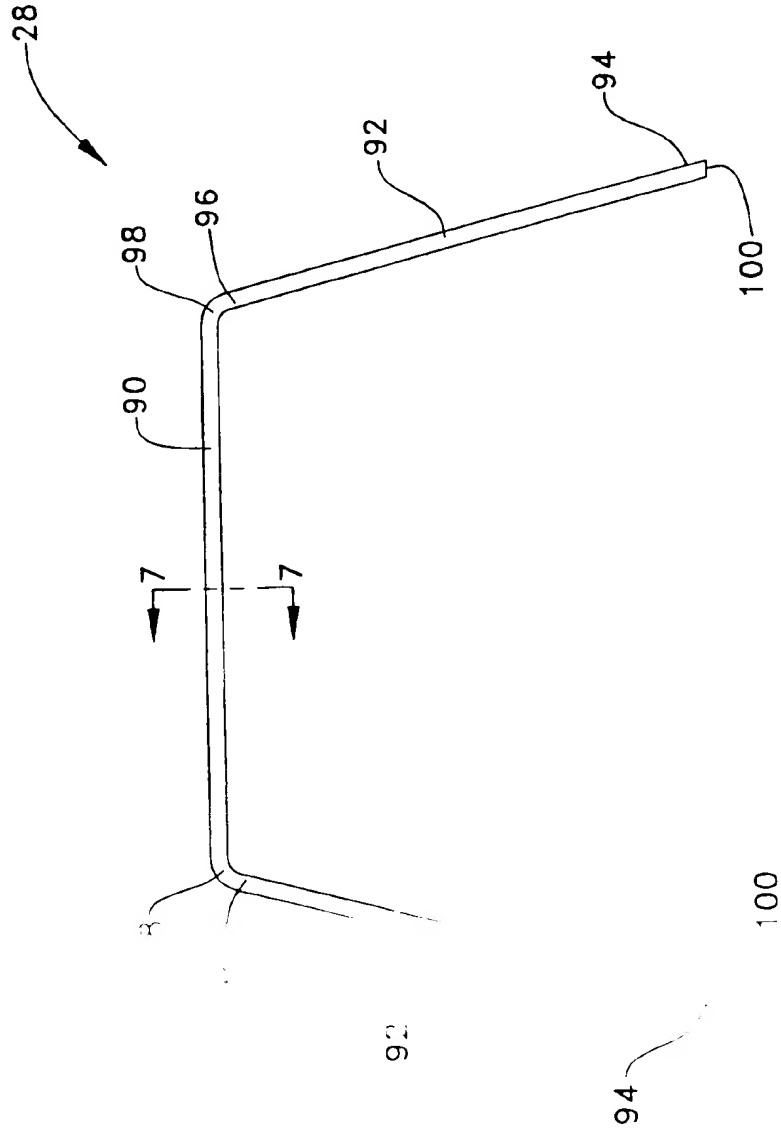


FIG-6



INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 F28D9/00 F02C7/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 F28D F02C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 081 834 A (DARRAGH CHARLES T) 21 January 1992	1,2,5,8, 10,11, 14-16, 18-20
A	see abstract see column 5, line 64 - column 7, line 55; figures 4-6	3,9,12

X	US 3 759 323 A (DAWSON HARRY J. ET AL) 18 September 1973	1,2,10, 11, 14-16, 18-20
A	see column 2, line 4 - column 3, line 59; figures	3,12

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex

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Van Dooren, M

INTERNATIONAL SEARCH REPORT

Ir ıtional Application No
PCT/US 98/23269

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	FR 2 704 310 A (SOCIÉTÉ D'ÉTUDES ET DE CONSTRUCTIONS AERO-NAVALES) 28 October 1994 see page 3, line 20 - page 4, line 31; figures 1,2	1,10
A	US 1 409 967 A (EMILE PRAT) 21 March 1922 see page 1, line 83 - line 104; figures 1-3	1,10
A	US 4 438 809 A (PAPIS THADDEUS) 27 March 1984 see figure 5	6,7

INTERNATIONAL SEARCH REPORT

Information on patent family members

Ir ational Application No
PCT/US 98/23269

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